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Agricultural Memorandum 894

The Effect of Cloud on Sunshine and Short Wave Radiation

by I. Barrie

Introduction

A combination equation of the type derived by Penman (1948) requires as one of the inputs an estimate for the net short wave radiation during the day.

The basis for this calculation has recently been improved by Cowley (1978) who calculated a set of constants to be used in a regression equation for areas within the UK.

The equation is of the form

$$R_S = R_a\left[\delta(a + b\,n/N) + (1-\delta)c\right] \qquad \text{W hr m}^{-2}$$

where R_S = short wave radiation

R_a = clear atmosphere short wave radiation

δ = 1 for sun: 0 for no sun

a and c are constants varying with locality

b is a constant varying by month and locality

n/N is the ratio of actual to possible sunshine.

This equation provides good estimates for R_S in assuming a linear relationship between R_S and n/N .

A linear relationship does not hold however for the dependence of radiation and sunshine on cloud amount.

A short investigation was carried out to determine these latter relationships and to give an approximate method whereby R_S may be calculated if only information on cloud cover is available.

I. The dependence of sunshine on cloud cover

Results from similar investigations have been published by Woodhead (1966, 1967) using data from East Africa and by Wartena (1959) from studies in Iraq.

Woodhead, using average monthly total cloud amounts at 0600 and 1200 GMT (0900 and 1500 local time) with the average daily sunshine value for the month produced two similar graphs, for Kenya and Tanzania, showing a curved relationship. The curve is convex to the origin and was fitted by eye.

To determine whether a similar relationship could be produced for the UK, cloud cover and sunshine data from Cardington were analysed over the period 1974 to 1979.

The form of the analysis differed from that by Woodhead in that the mean hourly daytime values of total cloud cover and the daily total of sunshine were used rather than the mean monthly values.

Although producing a greater degree of scatter the results proved to be very similar, see Fig. 1.

The shape of the curve becomes uncertain towards the zero cloud case but a reasonable fit was made using the following expression

$$n/N = 0.87 - 0.05(CTD) + 0.028(CTD)^2 - 0.005(CTD)^3 \qquad (1)$$

where CTD is the average total cloud cover during the day-time period and the maximum value is 7.4 oktas.

An accuracy of $\pm$ 0.2 is given in all but exceptional cases when say, a thin veil of cirrostratus had persisted all day and did not have sufficient density to reduce the measured sunshine total.

II. Calculated values of R_S compared to cloud cover ($R_{S(E)}$)

Taking his analysis a stage further Woodhead used the formula $R_S = R_a(0.23 + 0.53\, n/N)$ to compile tables for Kenya and Tanzania relating R_S to n/N.

He suggested that use of these tables and graphs for stations which reported cloud cover but not sunshine would enable an estimate of R_S to be made, for later use in evaporation calculations.

For the present analysis the Cowley (1978) formula was used with a = 0.22, c = 0.14 and monthly values of b varying from 0.44 to 0.54; these values being those found by Cowley for Cardington.

Again the analysis was done on a daily rather than a monthly basis producing, as before, a greater degree of scatter. Figure 2 shows the data for 1979 and indicates that a relationship similar to those from Kenya and Tanzania also holds true for Great Britain.

The separate group of points at the lower end of the graph illustrates the different method of calculations on occasions when $n/N = 0$.

III. Measured R_S compared to cloud cover ($R_{S(M)}$)

To give a more accurate representation of the data under extreme cloud conditions measured values of R_S were plotted against mean total cloud amounts on a daily basis, fig. 3.

The distribution is fairly similar to that shown in figure 2 except for occasions when the cloud cover exceeds 7 oktas. It highlights the problem of an increasingly rapid decrease in levels of R_s combined with a large spread of values for R_s/R_a when the cloud cover is complete.

In general there is not a marked decrease in values of R_s/R_a up to around 5 oktas, and the distribution is well fitted by

$$R_s/R_a = 0.65 + 0.035(CTD) - 0.012(CTD^2) \qquad (2)$$

giving an accuracy of $\pm$ 0.15 in nearly all cases.

Values of R_a, dependent on latitude and date, can be obtained from tables, or be calculated on a daily basis (Thompson, 1980).

To check for a monthly variation the data for each month was taken over the 6 year period and plotted on graphs similar to fig. 3. (see fig 3 e/f)

The general equation fitted to the data over the whole year still provided a good fit although the lines of best fit for the months of November, December and January tended to lie below the others. This is broadly consistent with Cowley's 'B' constants which are lowest during the winter months, but the amount of scatter and comparative scarcity of points for the lower cloud cases prevented a more detailed monthly analysis.

The values of $R_{s(M)}/R_a$ were plotted against average day-time low cloud data but no significant relationships could be found as the amount of scatter increased considerably.

Smith and Hunt (1978) observed when analysing hourly net (all wave) radiation data (R_{net}) from Cardington that R_{net} did not change significantly until the cloud cover had increased to over 6 oktas, after which a rapid reduction was noted.

The cloud cover corresponding to a maximum value of R_{net} was 2 oktas and is explained by the greater values of reflected light off cloud, diffuse radiation and long wave radiation from clouds more than compensating for the reduction in the direct component. Comparing this to fig. 3, despite using R_s on a daily basis rather than R_{net} hourly, the sharp decrease in R_s/R_a occurs at a similar value of cloud cover and there is an indication that R_s/R_a reaches a maximum value at around 2 oktas of cloud.

Discussion

The comparison between the East African data as analysed by Woodhead and that for Cardington indicates that the derived relationships can be applied to most, if not all, climatic areas.

There are minor differences between the two, especially around 0 and 8 oktas cloud cover where Whitehead extrapolated his line of best fit.

Taking the Cardington data on a daily basis this extrapolation was not necessary as greater detail at the extremes is obtained.

Further confirmation is provided for the Cowley, 1978, formula although his treatment on days with no sunshine is perhaps unsatisfactory.

Equations 1 and 2 provide methods for respectively, the calculation of a sunshine ratio and short wave radiation from average day-time total cloud.

Any comments or suggestions on this paper should be referred to the author.

Meteorological Office, Met O 8a
London Road
Bracknell
Berkshire

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1967 II, ibid, 32 pp 474-477.

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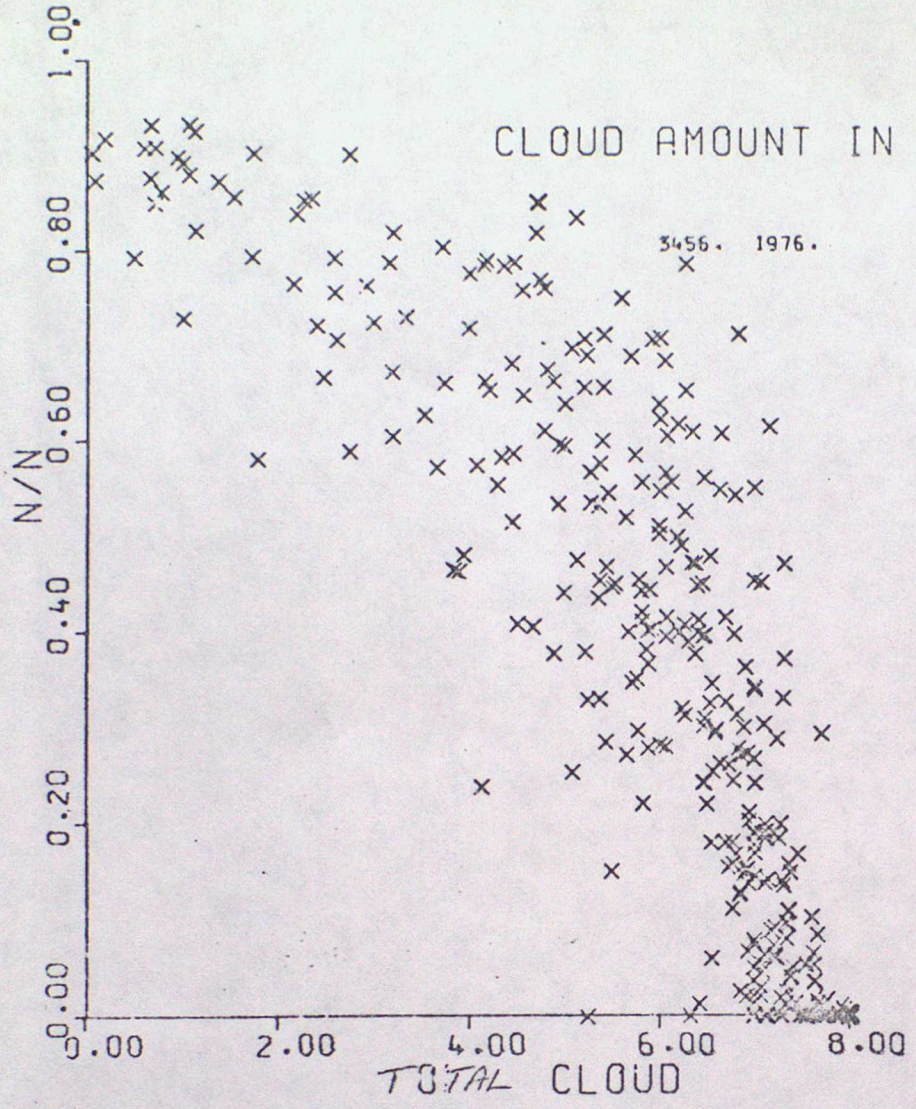
FIG 1 a/b


CLOUD AMOUNT IN EIGHTHS
3456. 1976.
N/N
1.00
0.80
0.60
0.40
0.20
0.00
0.00
2.00
4.00
6.00
8.00
TOTAL CLOUD

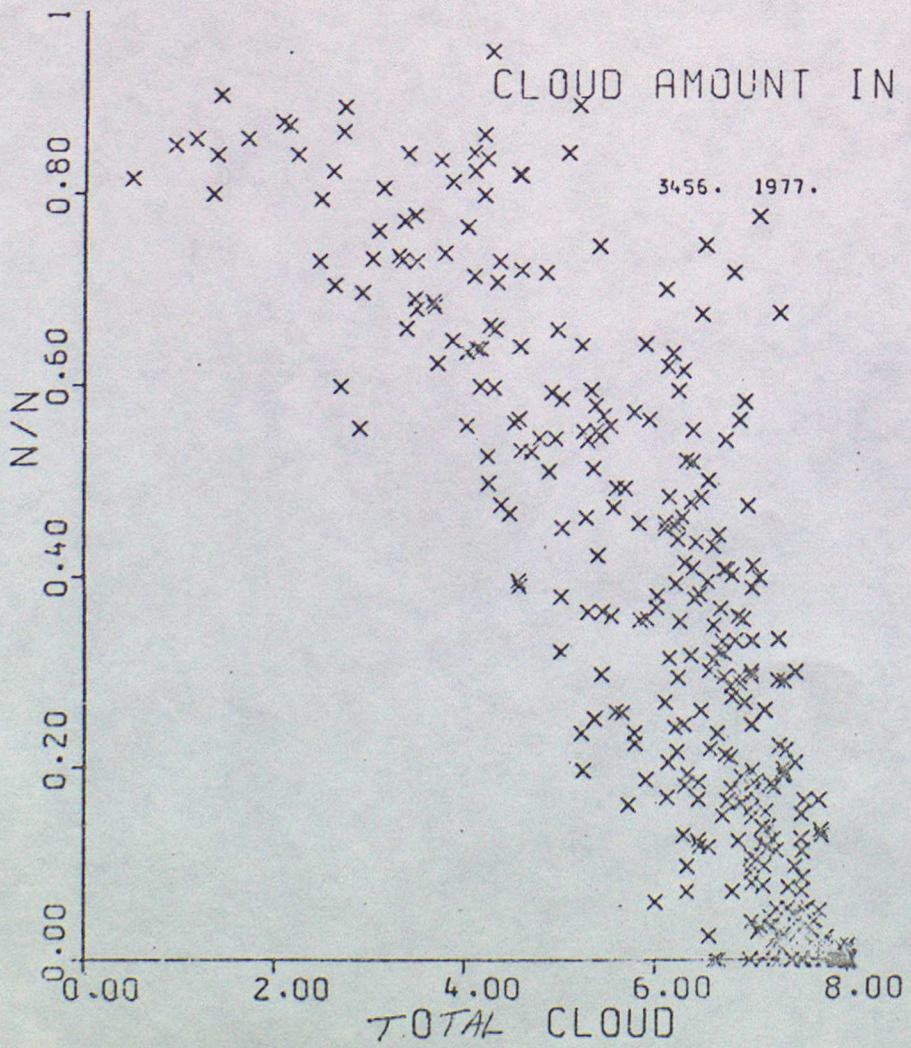
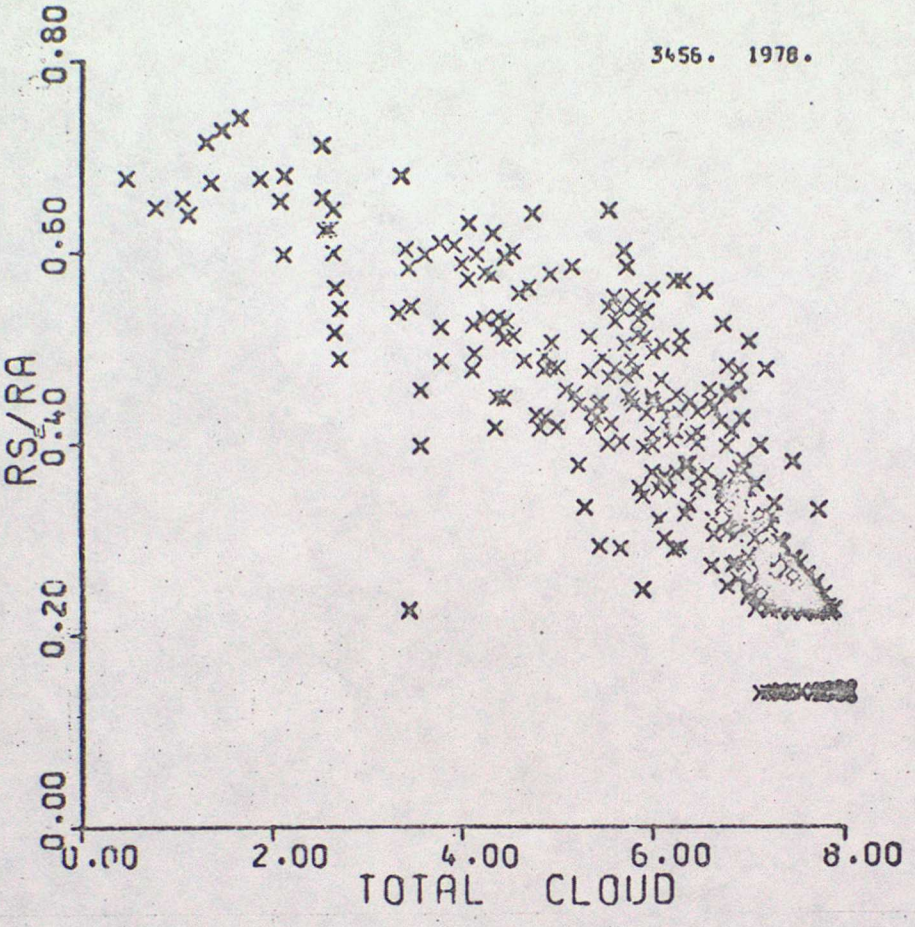

CLOUD AMOUNT IN EIGHTHS
3456. 1977.
N/N
1
0.80
0.60
0.40
0.20
0.00
0.00
2.00
4.00
6.00
8.00
TOTAL CLOUD

FIG 2

CLOUD AMOUNT IN EIGHTHS

3456. 1978.



CLOUD AMOUNT IN EIGHTHS

3456. 1979.

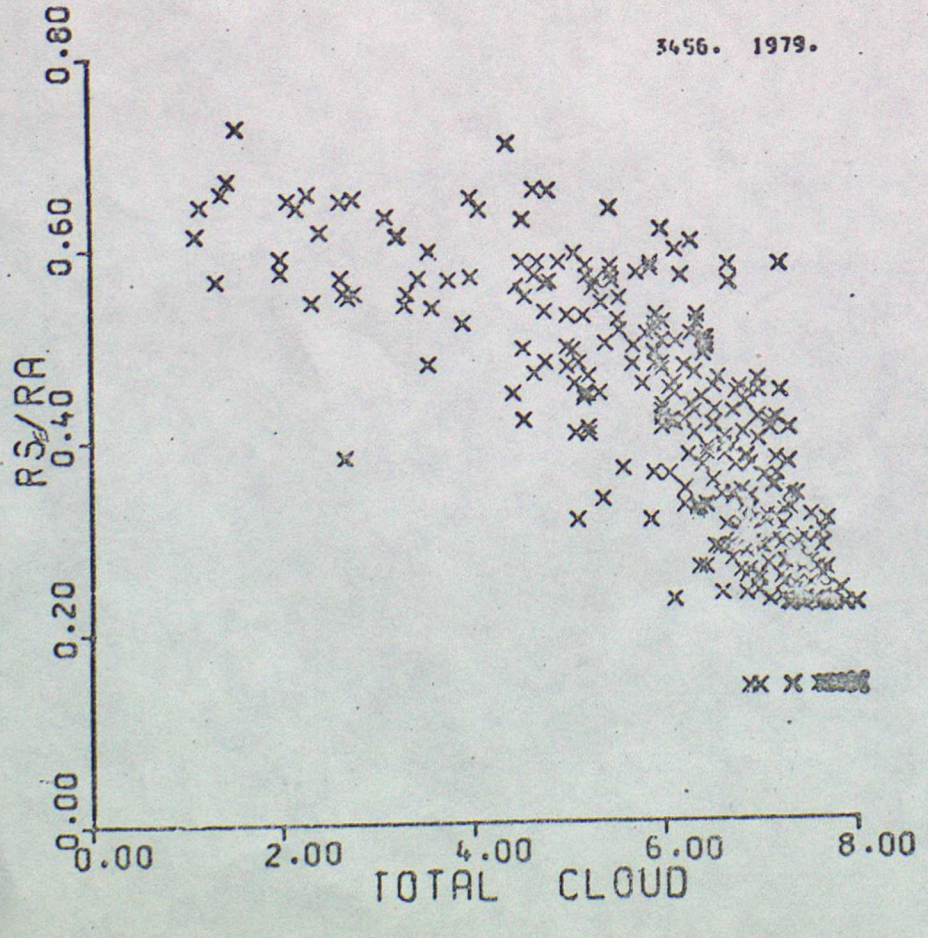
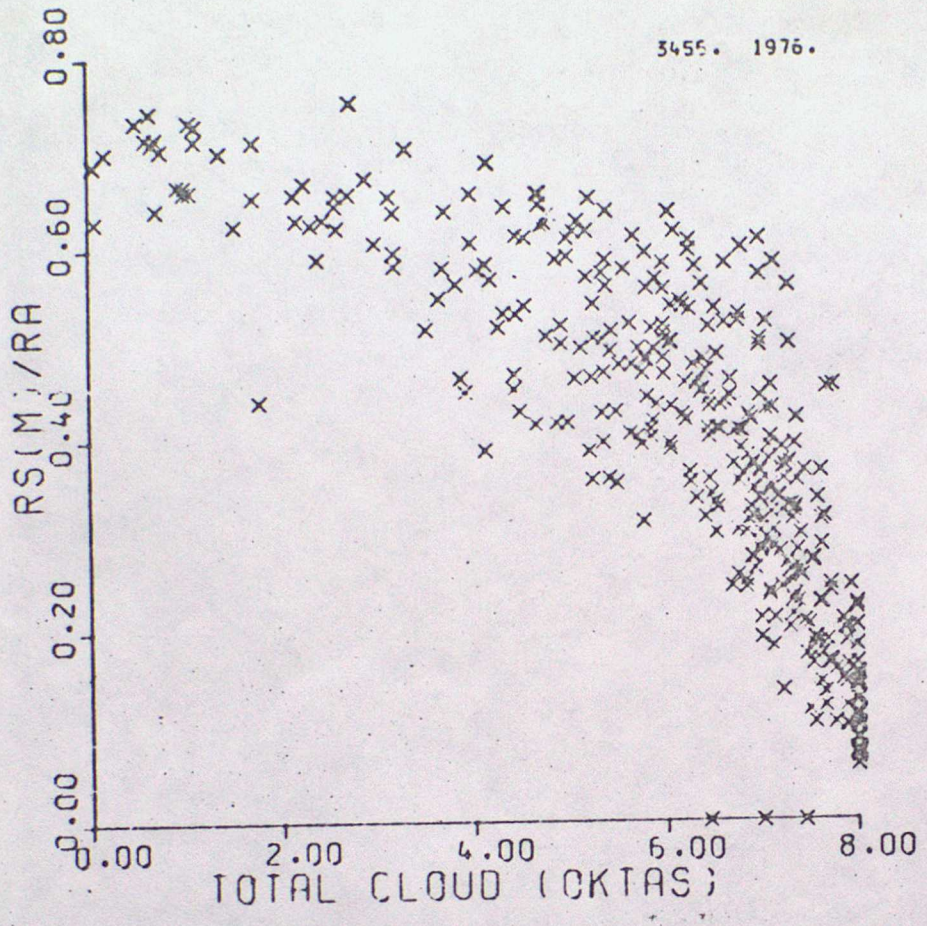


FIG 3 a/b.

RS(M)/RA VS DAYTIME CLOUD



RS(M)/RA VS DAYTIME CLOUD

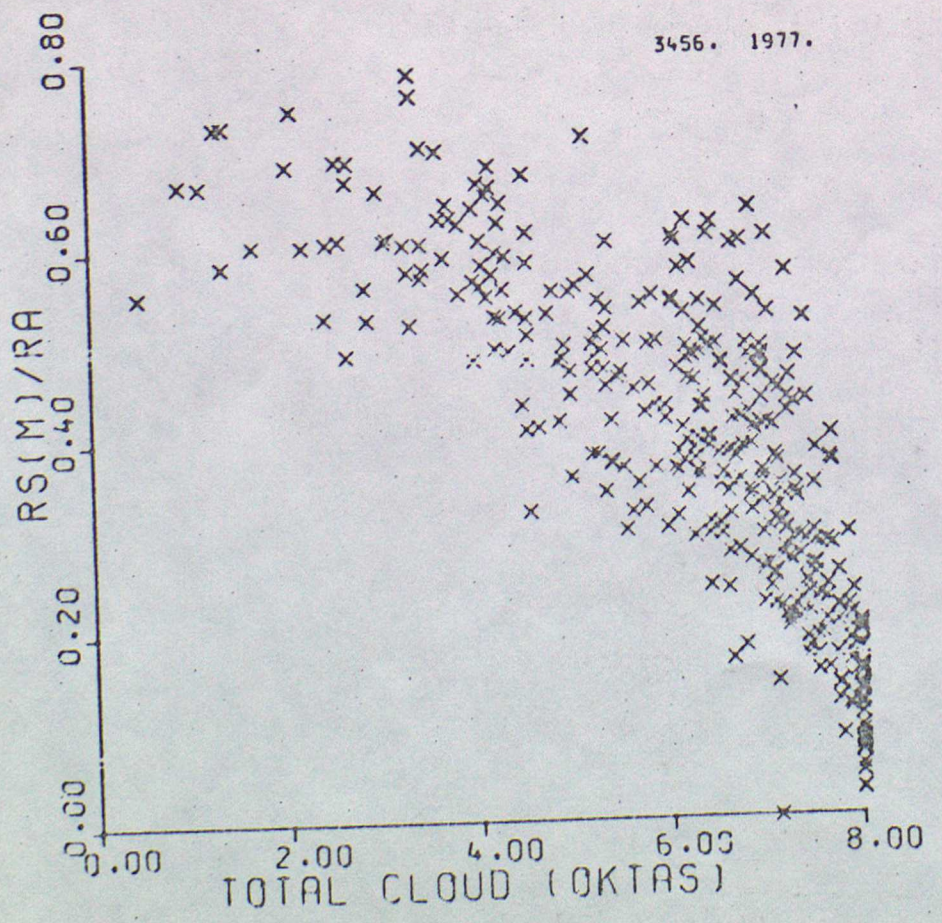
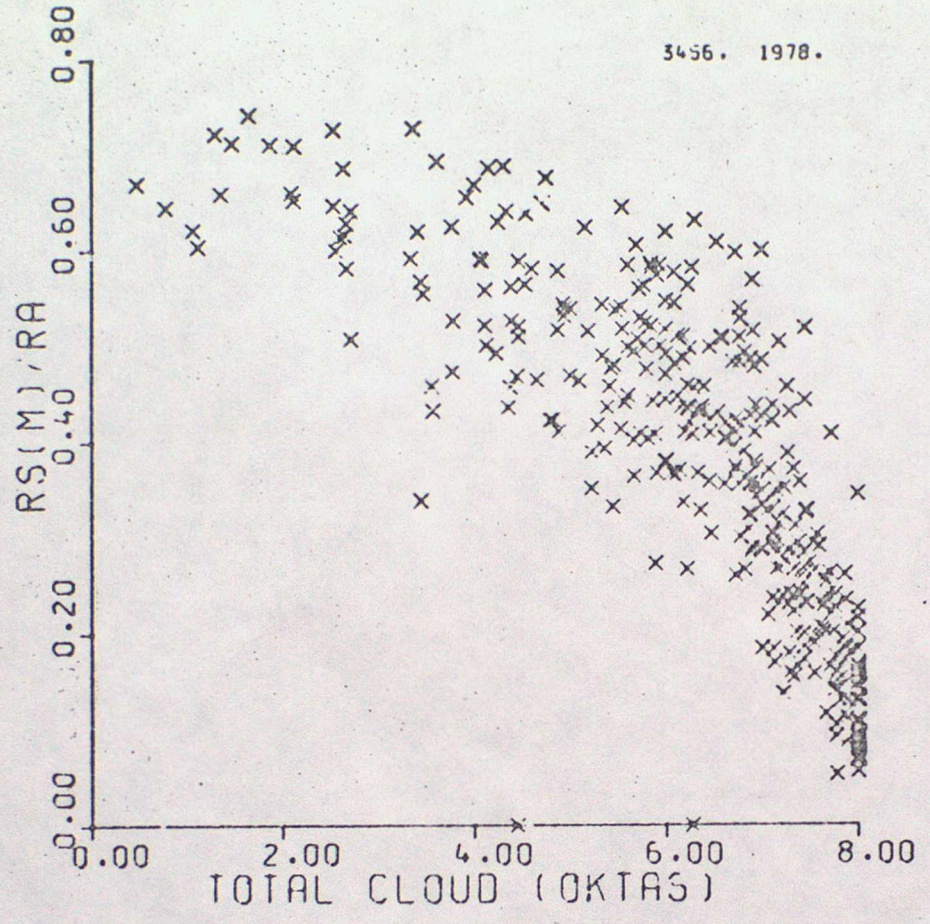


FIG 3 c/d

RS(M)/RA VS DAYTIME CLOUD



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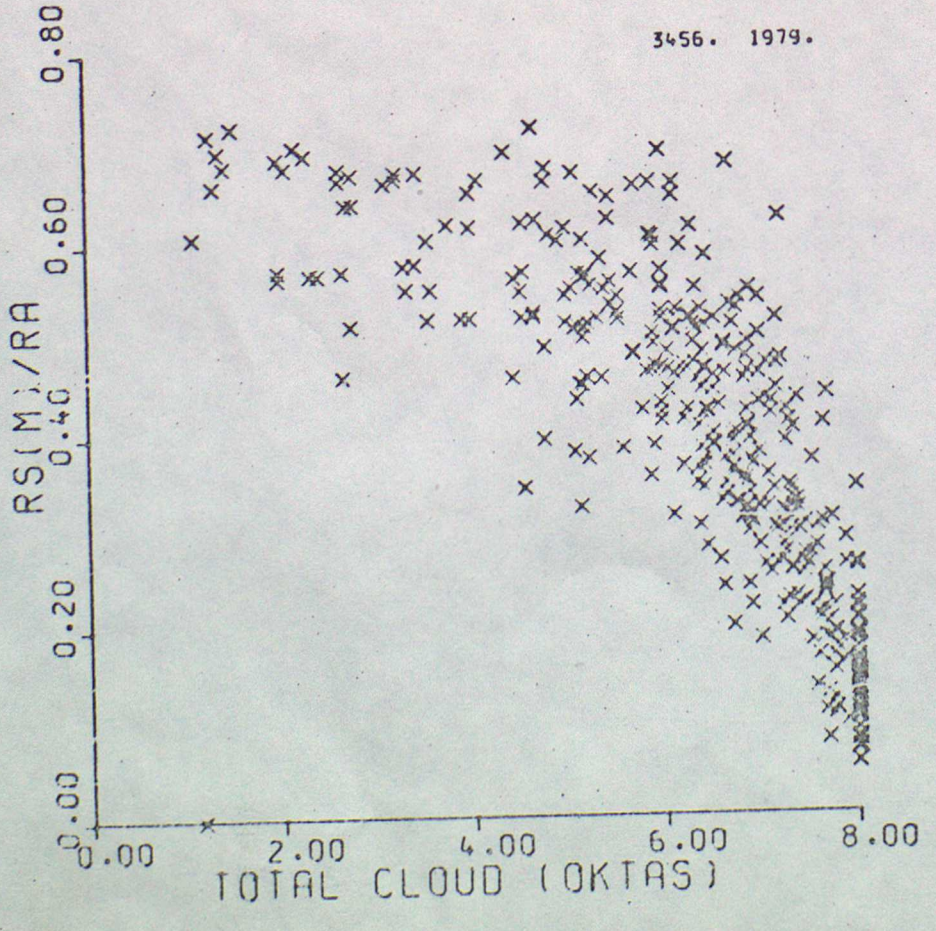
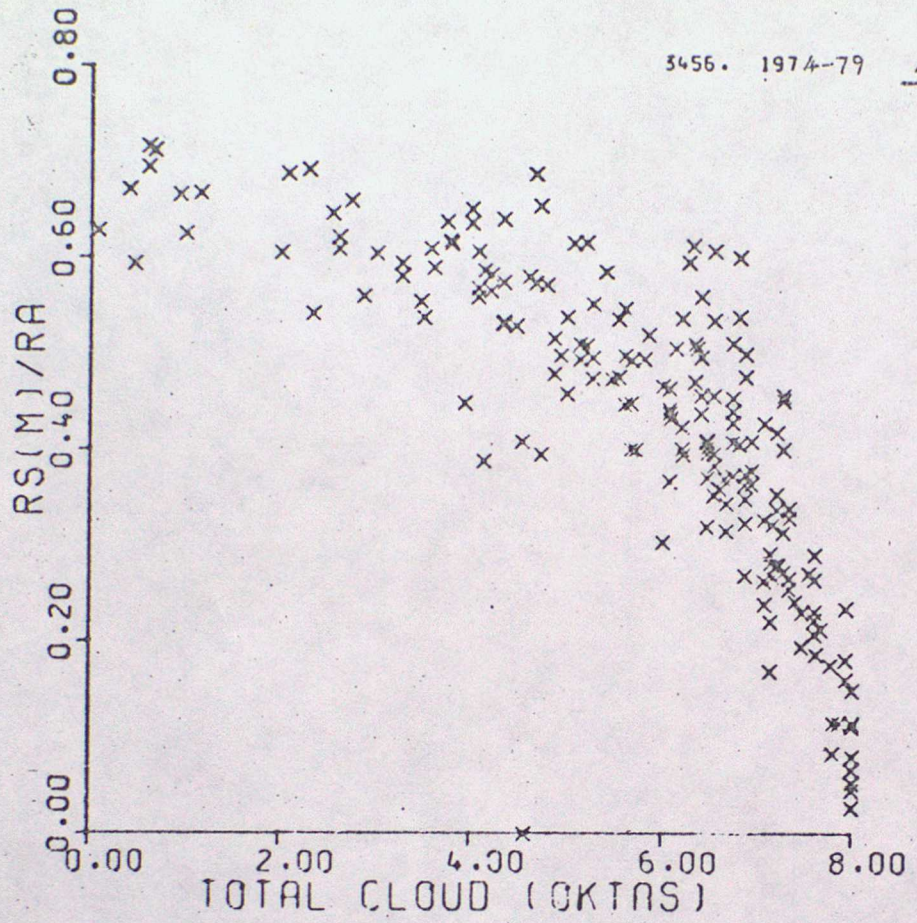


FIG 3 e/f.

RS(M)/RA VS DAYTIME CLOUD

3456. 1974-79 AUGUST



RS(M)/RA VS DAYTIME CLOUD

3456. 1974-79 NOVEMBER